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Planetary Geology

IMPACT CRATER EXPERIMENTS

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OBJECTIVE: To learn the mechanics of impact cratering.

METHOD: Observations of laboratory-produced craters and film of hypervelocity experiments; comparative analyses of lunar craters.

MATERIAL: Sand-filled tray,* supply of dyed sand, slingshot, projectiles, scale, cross-sections of hypervelocity-produced craters, and lunar photographs.

Prepare a smooth, flat sand surface by scraping the board across the sand tray. Ask instructor to emplace a layer of dyed sand over the prepared surface. Divide the target area into four (4) sections.

1. In one quarter-section, produce a crater using the slingshot to launch a 6 mm projectile fired normal (at 90°, or vertical) to the target surface. Sketch a plan (map) view and cross section of the crater. Be sure to sketch the pattern of the light-colored sand around the crater. This material is *ejecta*. Where did it come from?

What would you expect to find beneath the ejecta?

Would you expect the ejecta to be of equal thickness everywhere? What is its distribution and thickness in relation to the crater?

2. In the second quarter-section, produce a crater with a 6 mm projectile launched at about 65° to the surface (estimate the angle). Sketch the crater. Is there a *marked* difference between the two craters or ejecta patterns?

3. In the third quarter-section, produce a crater with a 6 mm projectile launched at about 40° to the surface. Be sure no one is "down range" in case the projectile ricochets. Sketch the crater.

4. In the fourth quarter-section, produce a crater with a 6 mm projectile launched at about 5–10° to the surface. Be sure no one is "down range" in case the projectile ricochets. Sketch the crater. Note the *asymmetric* cross section.

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*100μ sand is recommended. Sand can by dyed easily by mixing it with *dry* powdered tempera paint.

5. Examine the sand craters and your sketches. What are the relationships between impact angle, crater morphology (shape, form), and ejecta distribution?

6. Examine the photograph of the lunar crater Messier.* What interpretations can you make concerning its formation? Did the projectile which formed Messier enter from the east or west?

The next section deals with the relationships of projectile mass (weight) and velocity (average speed) to crater size.

7. Recover the projectiles from the experiments above and thoroughly mix the dyed and undyed sand to produce a uniform mixture. Smooth the target surface with the board. The remaining experiments will be performed *without* a dyed upper layer of sand.

Produce four (4) craters on the smooth target surface, using 8 mm projectiles. Make the first crater by dropping the projectile from a height of 10 cm above the surface, the second crater from a height of 2 m. The third projectile should be launched from the slingshot extended 23 cm (9"); the fourth, from the slingshot extended 36 cm (14"). Mass of projectile = 2 grams.

Complete the following table:

	*Velocity***	*Crater diameter*
Shot 1	2 cm/sec	_____
Shot 2	200 cm/sec	_____
Shot 3	1000 cm/sec	_____
Shot 4	3000 cm/sec	_____

8. Recover the projectiles and smooth the target surface with the board. Produce three (3) craters by dropping 4 mm, 9 mm, and 18 mm steel projectiles from a height of 2 m above the target surface. Record the crater diameter.

*See figure 18 "Impact Craters."
**Approximate

	Mass	*Crater diameter*
Shot 1 (4 mm)	.34	_____
Shot 2 (9 mm)	3.52	_____
Shot 3 (18 mm)	28.14	_____

9. Recover the projectiles and smooth the target surface with the board. Produce three (3) craters by dropping 18 mm steel, glass, and hollow aluminum projectiles* from a height of 2 m above the target surface. Record the crater diameter.

	Mass	*Crater diameter*
Shot 1 (steel)	28.14	_____
Shot 2 (glass)	8.07	_____
Shot 3 (hollow aluminum)	2.37	_____

10. From observations of your experiments, answer the following questions concerning impact cratering:

a. In producing craters, which is more important, projectile *diameter* or projectile *mass*?

b. What is the relationship between projectile velocity and crater size?

Impacts involve the transfer of energy from the projectile to the target. *Kinetic energy* (energy in motion), K.E. = ½ mv^2, where m = mass (weight) and v = velocity. The above exercises involved *iow velocity* impacts (maximum velocities of only a few *meters* per second). Natural impact events commonly occur at velocities of more than 10 *kilometers* per second (22,500 mph!); "projectile" mass (meteorites) may be several kilotons.

11. Determine the amount of energy involved in producing the crater for "Shot 2" of Question 7.

$$K.E. = \tfrac{1}{2} mv^2$$

*Projectiles available from Industrial Techtronics, P.O. Box 1128, Ann Arbor, Michigan 48106.

12. Determine the kinetic energy for an iron meteorite 20 m in diameter (mass = 3.34×10^{10} g), impacting at a velocity of 10 km/sec. For comparison, 1 kiloton of TNT = 4.2×10^{19} ergs.

13. Investigation of *hypervelocity* (high velocity) impacts requires extensive laboratory equipment. Your instructor will explain hypervelocity impact studies performed at NASA-Ames and show high speed motion pictures of impact events produced by a *Hydrogen Gas Gun.*

View the film and note the sequence of events in crater formation. The flash of light seen during the initial stage of impact resulted from "impact-shocked" electrons shifting from one orbit to another within the molecular structure of the sand. A significant part of the kinetic energy of impacting projectiles is transformed to *heat*. This heat often melts part of the target or planetary surface. Explain the geological significance of this fact.

Examine the slabs* prepared from targets impacted in the NASA-Ames light gas gun. In the space below sketch the "rock" layers.

a. Is the crater rim higher, lower, or the same level as the original target surface?

b. Trace the uppermost "formations" (colored sand layers) through the rim. What happens to these units?

c. Are the units in the crater walls of uniform thickness?

d. What happens to the units beneath the crater floor?

14. Examine the film† and photograph** of "Mare Exemplum" produced at NASA-Ames Research Center.

a. Pick out a large crater and describe the changes that occur as it "ages" with time.

*See figure 10(a) "Impact Craters."

**See figure 17 "Impact Craters."

†Film "Mare Exemplum" available from Public Affairs, NASA-Ames, Moffett Field, CA.

b. Select a large crater formed late in the sequence. How does its ejecta alter the surrounding surface?

c. Is impact-cratering an effective erosive process? Would it be as effective on Earth as on the Moon? On Mars?

d. Considering the lunar surface, would it be possible to obtain "relative" age dates for different geological units on the basis of crater statistics? Could you obtain "absolute" age dates? Explain.